

WHAT IS CLAIMED IS:

1. A crystallization apparatus comprising:

5 a phase modulation element in which a phase of outgoing light beams relative to incident light beams differs depending on each position; an illumination system used to generate the incident light beams which enter the phase modulation element; an image formation optical system provided on an outgoing radiation side of the phase modulation element; and a stage used to support a substrate having a non-single crystal semiconductor film provided on an outgoing radiation side of the image formation optical system,

10 wherein the phase modulation element has a phase distribution based on a phase modulation unit which is optically smaller than a radius of a point spread distribution range of the image formation optical system when converted to an image formation surface of the image formation optical system.

20 2. The crystallization apparatus according to claim 1, wherein the phase modulation element has a phase distribution that area shares of a first area having a first phase value and a second area having a second phase value vary depending on each position.

25 3. The crystallization apparatus according to claim 2, wherein the phase modulation element has a plurality of cells each of which is optically smaller than the radius of the point spread distribution range

of the image formation optical system converted to the image formation surface or the predetermined surface of the image formation optical system, and the area shares of the first area and the second area vary in accordance with each cell.

4. The crystallization apparatus according to claim 2, wherein the phase modulation element has a plurality of pixels each of which is optically smaller than the radius of the point spread distribution range of the image formation optical system when converted to the image formation surface or the predetermined surface of the image formation optical system, each pixel has a fixed phase value, and the number of pixels having the same phase value per unit range optically corresponding to the point spread distribution range varies in accordance with each unit range.

5. The crystallization apparatus according to claim 2, wherein the phase modulation element has a plurality of stripe-like areas each of which has an optically smaller width than the radius of the point spread distribution range of the image formation optical system when converted to the image formation surface or the predetermined surface of the image formation optical system, each stripe-like area has a fixed phase value, and a width of each stripe-like area varies along a longitudinal direction.

6. The crystallization apparatus according to

claim 2, wherein the phase modulation element has
a line-and-space pattern whose width is optically
smaller than the radius of the point spread
distribution range of the image formation optical
5 system when converted to the image formation surface or
the predetermined surface of the image formation
optical system, each line portion has a first phase
value, each space portion has a second phase value, and
a ratio in width of the line portion and the space
10 portion which are adjacent to each other varies along
a widthwise direction.

7. The crystallization apparatus according to
claim 1, wherein the phase modulation element has
a cyclic divided area structure, each divided area has
15 a fixed phase value, and the phase modulation element
has a phase distribution that a phase value varies in
accordance with each divided area.

8. The crystallization apparatus according to
claim 7, wherein the phase modulation element has
20 a plurality of pixels each of which is optically
smaller than the radius of the point spread
distribution range of the image formation optical
system when converted to the image formation surface or
the predetermined surface of the image formation
25 optical system, each pixel has a fixed phase value, and
the phase value varies in accordance with each pixel.

9. The crystallization apparatus according to

claim 7, wherein the phase modulation element has
a line-and-space pattern whose width is optically
smaller than the radius of the point spread
distribution range of the image formation optical
5 system when converted to the image formation surface or
the predetermined surface of the image formation
optical system, and the phase value varies in
accordance with each line portion.

10. The crystallization apparatus according to
10 claim 1, wherein the phase modulation element has
a first stripe-like area which has a first phase
distribution and extends in a direction along which
a phase varies and a second stripe-like area which has
a second phase distribution and extends in the
15 direction along which the phase varies, the first
stripe-like area and the second stripe-like area are
adjacent to each other with a border line parallel
with the direction along which the phase varies
therebetween, and an average phase value on the first
20 stripe-like area side is substantially different from
an average phase value on the second stripe-like area
side in a local area on the border line.

11. The crystallization apparatus according to
claim 10, wherein the first stripe-like area and the
25 second stripe-like area are configured to have
substantially the same light intensity distributions
which are formed in accordance therewith, the average

phase value on the first stripe-like area side is substantially different from the average phase value on the second stripe-like area side in a first local area on the border line corresponding to a part where
5 a light intensity in the light intensity distribution is small, and the average phase value on the first stripe-like area side is substantially equal to the average phase value on the second stripe-like area side in a second local area on the border line corresponding
10 to a part where a light intensity in the light intensity distribution is large.

12. The crystallization apparatus according to claim 11, wherein the first stripe-like area and the second stripe-like area have a line-and-space pattern
15 whose width is optically smaller than the radius of the point spread distribution range of the image formation optical system when converted to the image formation surface or the predetermined surface of the image formation optical system, each line portion has the
20 first phase value, each space portion has the second phase value, and a ratio in width of the line portion and the space portion which are adjacent to each other varies in a widthwise direction.

13. The crystallization apparatus according to claim 11, wherein the first stripe-like area and the
25 second stripe-like area have a line-and-space pattern whose width is optically smaller than the radius of

the point spread distribution range of the image formation optical system when converted to the image formation surface or the predetermined surface of the image formation optical system, and a phase value
5 varies in accordance with each line portion.

14. The crystallization apparatus according to claim 1, wherein the phase modulation element comprises isolated areas each of which is optically smaller than the radius of the point spread distribution range of
10 the image formation optical system when converted to the image formation surface or the predetermined surface of the image formation optical system and has a phase value which is substantially different from that of the periphery in accordance with parts where
15 a light intensity of a light intensity distribution to be formed is small.

15. The crystallization apparatus according to claim 1, wherein the phase modulation element turns the incident light beams to a light intensity
20 distribution with a concave pattern that a light intensity is increased toward the periphery from a central area having a first light intensity.

16. The crystallization apparatus according to claim 15, wherein the light intensity distribution with the concave pattern has a distribution that the light
25 intensity is one-dimensionally increased from the central area toward the periphery.

17. The crystallization apparatus according to claim 15, wherein the predetermined light intensity distribution has a light intensity distribution with an inverse peak pattern that the light intensity is suddenly increased toward the periphery from a second central area having a second light intensity substantially smaller than the first light intensity in the vicinity of the central area of the light intensity distribution with the concave pattern.

18. The crystallization apparatus according to claim 16, wherein the predetermined light intensity distribution has a light intensity distribution with an inverse peak pattern that the light intensity is suddenly increased toward the periphery from a second central area having a second light intensity substantially smaller than the first light intensity in the vicinity of the central area of the light intensity distribution with the concave pattern.

19. An exposure apparatus comprising:

a phase modulation element in which a phase of outgoing light beams relative to incident light beams differs depending on each position; an illumination system used to generate the incident light beams which enter the phase modulation element; an image formation optical system provided on an outgoing radiation side of the phase modulation element; and an image formation optical system arranged in a light path between

the phase modulation element and a predetermined surface,

5 wherein the phase modulation element has a phase distribution based on a phase modulation unit which is optically smaller than a radius of a point spread distribution range of the image formation optical system when converted to an image formation surface of the image formation optical system.

20. A crystallization method comprising:

10 illuminating a phase modulation element having a phase distribution based on a phase modulation unit which is optically smaller than a radius of a point spread distribution range of an image formation optical system when converted to an image formation surface;
15 and

irradiating a polycrystal semiconductor film or an amorphous semiconductor film with light beams having a predetermined light intensity distribution through the image formation optical system arranged in a light
20 path between the phase modulation element and the polycrystal semiconductor film or the amorphous semiconductor film, thereby generating a crystallized semiconductor film.

21. A crystallization method comprising:

25 illuminating a phase modulation element having a phase distribution based on a phase modulation unit which is optically smaller than a radius of a point

spread distribution range of an image formation optical system when converted to an image formation surface; and

5 forming a predetermined light intensity distribution on a predetermined surface through the image formation optical system arranged in a light path between the phase modulation element and the predetermined surface.

10 22. A phase modulation element having a phase distribution based on a phase modulation unit having a predetermined size, comprising:

 a first area having a first phase value; and
 a second area having a second phase value,
 wherein the phase distribution is defined by
15 a change in area shares of the first area and the second area depending on each position.

 23. The phase modulation element according to claim 22, wherein the phase modulation element has a plurality of cells, and area shares of the first area
20 and the second area in each cell vary in accordance with each cell.

 24. The phase modulation element according to claim 22, wherein the phase modulation element comprises a plurality of pixels each having a fixed
25 phase value, and the number of pixels having the same phase value per unit range varies in accordance with each unit range.

25. The phase modulation element according to claim 22, wherein the phase modulation element comprises a plurality of stripe-like areas each having a fixed phase value, and a width of each stripe-like area varies along a longitudinal direction.

26. The phase modulation element according to claim 22, wherein the phase modulation element has a line-and-space pattern which includes a plurality of line portions each having the first phase value and a plurality of space portions each having the second phase value, and a ratio in width of the line portion and the space portion which are adjacent to each other varies along a widthwise direction.

27. A phase modulation element having a phase distribution based on a phase modulation unit having a predetermined size, comprising:

a plurality of divided areas each having a fixed phase value,

wherein each of the divided areas has a phase distribution that the phase value cyclically varies in accordance with each divided area.

28. The phase modulation element according to claim 27, wherein the phase modulation element comprises a plurality of pixels each having a fixed phase value, and the phase value of each pixel varies in accordance with each pixel.

29. The phase modulation element according to

claim 27, wherein the phase modulation element has a line-and-space pattern, and a the phase value varies in accordance with each line portion.

30. A phase modulation element having a phase
5 distribution based on a phase modulation unit having a predetermined size, comprising:

a first stripe-like area which has a first phase distribution and extends in a direction along which a phase varies; and

10 a second stripe-like area which has a second phase distribution and extends in the direction along which the phase varies,

wherein the first stripe-like area and the second stripe-like area are adjacent to each other with
15 a border line parallel with the direction along which the phase varies therebetween, and an average phase value on the first stripe-like area side is substantially different from an average phase value on the second stripe-like area side in a local area on the
20 border line.

31. The phase modulation element according to claim 30, wherein the first stripe-like area and the second stripe-like area are configured to have substantially the same light intensity distributions
25 which are formed in accordance therewith, the average phase value on the first stripe-like area side is substantially different from the average phase value on

the second stripe-like area side in a first local area on the border line corresponding to a part where a light intensity in the light intensity distribution is small, and the average phase value on the first stripe-like area side is substantially equal to the average phase value on the second stripe-like area side in a second local area on the border line corresponding to a part where a light intensity in the light intensity distribution is large.

32. The phase modulation element according to claim 30,

wherein the first stripe-like area and the second stripe-like area have a line-and-space pattern, each line portion has a first phase value, each space portion has a second phase value, and a ratio in width of the line portion and the space portion which are adjacent to each other varies along a widthwise direction.

33. The phase modulation element according to claim 31,

wherein the first stripe-like area and the second stripe-like area have a line-and-space pattern, each line portion has a first phase value, each space portion has a second phase value, and a ratio in width of the line portion and the space portion which are adjacent to each other varies along a widthwise direction.

34. The phase modulation element according to claim 30,

wherein the first stripe-like area and the second stripe-like area have a line-and-space pattern, and the phase value of the line portion varies in accordance with each line.

35. The phase modulation element according to claim 31,

wherein the first stripe-like area and the second stripe-like area have a line-and-space pattern, and the phase value of the line portion varies in accordance with each line.

36. The phase modulation element according to claim 22, wherein the phase modulation element comprises isolated areas each of which has a phase value which is substantially different from that of a periphery in accordance with parts where a light intensity in a light intensity distribution to be formed is small.

37. A device comprising:

a semiconductor film manufactured by a crystallization method, the crystallization method comprising: illuminating a phase modulation element having a phase distribution based on a phase modulation unit which is optically smaller than a radius of a point spread distribution range of an image formation optical system when converted to an image formation

surface; and forming a predetermined light intensity distribution on a predetermined surface through the image formation optical system arranged in a light path between the phase modulation element and the predetermined surface.

38. A display apparatus comprising:

a pair of substrates joined to each other with a predetermined gap therebetween;

an electro-optic material held in the gap;

an opposed electrode formed on one of the substrates; and

a semiconductor thin film which can provide pixel electrodes formed on the other substrate and thin film transistors which drive the pixel electrodes,

wherein the semiconductor thin film is a semiconductor film crystallized by irradiating the polycrystal semiconductor film or the amorphous semiconductor film with light beams having a predetermined light intensity distribution through a phase modulation element in which a phase of outgoing light beams relative to incident light beams varies depending on each position and an image formation optical system.